R & D ACTIVITY ON HIGH QE ALKALI PHOTOCATHODES FOR RF GUNS

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ABSTRACT

R&D on high quantum efficiency (QE) alkali photocathode is in progress at Milano in the context of the ARES-TTF (Tesla Test Facility) program. High QE multialkali antimonide and cesium telluride cathodes have been produced in an advanced preparation system. Photoemitter's preparation procedures have been set-up, in collaboration with the SESAMO lab. of the University of Modena, using Auger Electron Spectroscopy (AES): AES technique was used, in conjunction with sputter erosion, to obtain the in-depth profile of the photoemissive film. In this way photocathode preparation parameters (substratum cleaning procedure and temperature, alkali metal deposition rate, etc.) have been optimised. The spectral response of the photocathodes and the QE spatial distribution over the cathode surface has been measured using different light sources (254 nm < λ < 670 nm) and an optical scanning system. The photocathode poisoning effect and the changes in the photoemissive response due to the reaction with different gases have been investigated exposing the photoemitters, in a controlled way, to methane, carbon monoxide, carbon dioxide and oxygen. The good results so far obtained brought in Milano the responsibility of the production of cesium telluride photocathodes for the TTF Injector II. A preparation system for this application will be operative at Argonne within the end of 1995.

INTRODUCTION

Alkali based photoemissive materials have been widely used in television camera tubes, photomultipliers and image intensifier devices. Moreover, in the last years a big effort has been devoted to their operation as electron sources inside RF guns, in order to obtain high intensity, high current density electron pulses. A more detailed discussion about the characteristics of photoemitters to be used in an high current injector have been extensively discussed elsewhere [1-4]. Usually the choice of the photoemissive material together with its preparation procedure has been optimised empirically. The Milano and Modena group R&D activity on photocathodes is mainly devoted to overcome this philosophy, applying surface analysis technique (AES, XPS) to go over the alchemy of photocathode preparation and operation. At Milano an advanced UHV preparation system [5] is operative (base pressure is $1\cdot10^{-11}$ mbar) to produce photoemissive materials without contamination while, at Modena, a simplified preparation chamber [6], connected to a multitechnique analysis system (AES and depth profile AES), gives the opportunity to analyse "in situ" prepared photoemitters.

Our activity started with the investigation of alkali antimonide photocathodes: this choice had been induced by the high quantum efficiency (QE) that characterize these materials in visible light range. The result obtained so far for cesium antimonide (Cs_3Sb) are discussed in reference [1]. The R&D activity is now devoted to investigate more robust and stable photoemitters: in this paper we will discuss the results so far obtained on K_2CsSb and the preliminary data obtained on Cs_2Te photoemissive materials.

EXPERIMENTAL

A reproducible recipe for the preparation of stable cesium potassium antimonide photoemissive films with high QE (on a AISI 304 SS substratum) has been worked out with the support of the AES and depth profile AES techniques.

A typical preparation procedure of a K_2CsSb layer starts with the preparation of a Cs_3Sb layer as described in ref. 5 e 6. The AES investigation has shown that, using this procedure, we obtain a photoemissive layer with a chemical composition similar to that of Cs_3Sb Fig. 2A.

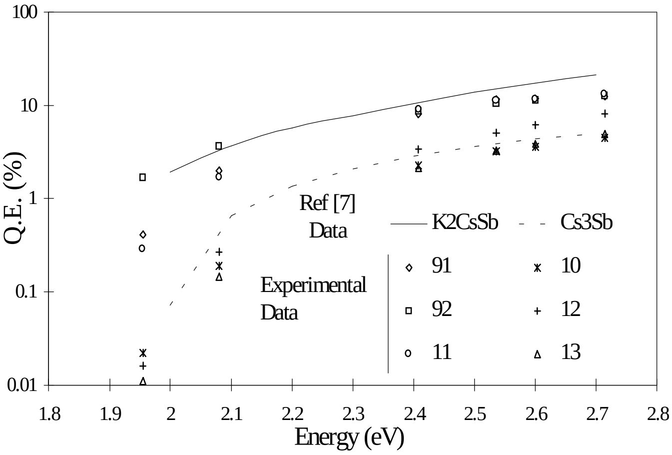

Fig. 1 - Comparison of the spectral response of different kind of cathodes prepared in our lab (K_2CsSb and Cs_3Sb) with the data reported by Sommer [7]. See text for more details.

This composition has been also confirmed by the comparison of the spectral response of this photoemitter with the K_2CsSb produced following the "recipe" here described and also comparing the data we found in literature [7]. This comparison is shown in fig.1. After the cesium deposition, the cathode temperature is raised from 120 °C to 230 °C in a few tens of minutes, maintained at this temperature for about

60 minutes and then is lowered at 120 °C. At the end of this procedure photoemission is nearly completely destroyed and the QE is lower then 10^{-3} % (@ 543 nm). An AES depth profile performed at this step of the preparation procedure shows that the layer contains not only antimony but also both alkali metals (see Fig. 2B).

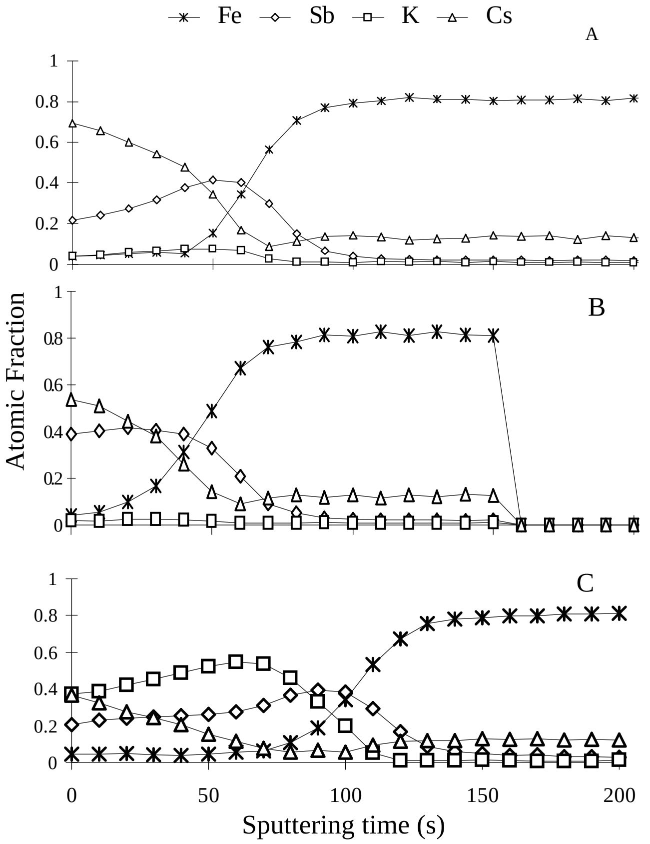

Fig. 2 - AES depth profiles after each step of the K_2CsSb cathode growth: 2A Cs_3Sb layer; 2B at the end of the 230 °C heating procedure; 2C on the definitive K_2CsSb layer.

The next step of the K_2CsSb preparation consists of potassium evaporation: as soon as we heat the K source the photocurrent presents a very rapid increase. The behaviour of the photocurrent during the potassium evaporation is shown in Fig. 3.

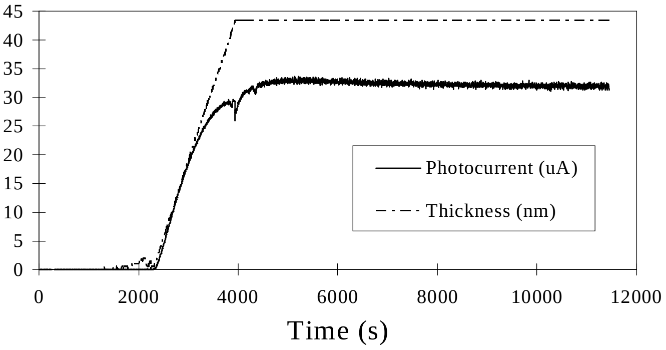

Fig 3 - K_2CsSb cathode photocurrent (@ 543 nm) and K thickness during the last step of the preparation procedure.

An AES depth profile analysis performed on the final layer shows that the chemical composition, at an estimated depth of about 5 nm, is close to the K_2CsSb one (see fig. 2C).

Unfortunately, in front of high QE characteristics, K_2CsSb photoemissive films presents an high reactivity with different gases and these are probably the main phenomena that affect the operation of such a material in a gun. We could investigate the poisoning effect using the Milano preparation system that operates with a base pressure lower than $1.5\cdot10^{-11}$ mbar, and is endowed with an accurate gas injection system. K_2CsSb films present a very high reactivity with oxygen and carbon dioxide, while they are rather insensible to methane, carbon monoxide and hydrogen exposition [6].

We have measured also the K_2CsSb spectral response during the poisoning with oxygen: data are shown in Fig. 4.

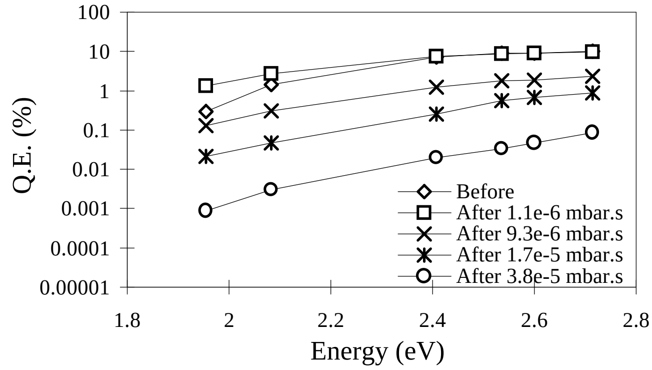

Fig4 - QE variation in K_2CsSb during the poisoning with oxygen.

The enhancement in the cathode response with respect to red light, reported by Sommer [7], is clearly visible after the first exposition. Unfortunately in the following steps the QE rapidly decreases. These measurements confirm the high reactivity of these materials (e.g. 10 ML of oxygen destroy completely the K_2CsSb photoemissive properties) and therefore forces the operation of these photocathode in extremely UHV conditions. The operation of Cs_3Sb and K_2CsSb photoemitters in RF guns is so limited to a few tens of minutes or, at best , to a few hours [8]. This drawback has to be overcome to ensure a reasonably long gun operation.

The strategy followed is to produce more robust and less poisonable photocathodes with a consequent longer lifetime. Following the experience of other laboratories such as LANL [9] and CERN [10], we are now beginning a systematic investigation of the properties of Cs_2Te, using the same procedure we applied in the alkali antimonide photoemitter R&D. Cesium telluride promises to be, at this time, the more probable candidate as the photocathode material for the future guns.

The preparation procedure of a Cs_2Te cathode follows a “recipe” similar to that used at CERN [10] and at LANL. [9] Tellurium is evaporated using a NiCr dispenser, similar to that used for alkali metals (SAES Getters) and antimony, filled with 99.999 % tellurium powder. After filling the tellurium is melted, under helium atmosphere, inside the dispenser in order to avoid any leakage of the Te powder.

A typical preparation procedure can be described schematically by three mayor steps.

- Molybdenum substratum conditioning. A molybdenum sample is cleaned using the standard procedure used for UHV components: degreasing in a ultrasonic cleaners by successive immersion in MEK and alkaline soap, rinsing in pure water, drying in high purity ethyl alcohol and baking, under UHV, up to 180 °C for some hours.
- Tellurium deposition: a layer of about 5 nm is deposited on the Mo substratum, at a deposition rate of about 1 nm/min.
- Cesium deposition: by heating the proper dispenser cesium is evaporated (dep. rate is about 1 nm/min, substratum is maintained at room temperature) and the alkali metal deposition is continued until a maximum in the photocurrent is reached.

A Cs_2Te cathode preparation procedure is illustrated in Fig.5 where the typical behaviour of the photocurrent (@ 254 nm, 10.4 µW) together with the thickness of the tellurium and cesium films are shown.

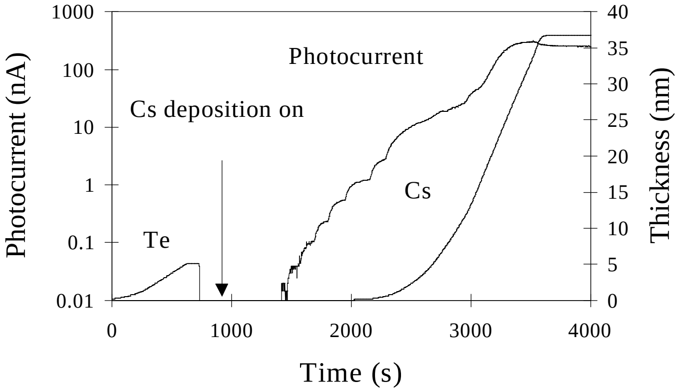

Fig. 5 - Cs_2Te cathode photocurrent together with Te and Cs thickness during the cathode preparation.

Typical QE value of Cs_2Te cathode that we have prepared are reported in the Tab. 1. The UV source is a 100 W high pressure mercury lamp (Oriel 6281) and the power measurement detector is a Coherent LMP2-UV.

Table 1. Cs_2Te QE at different wavelength

λ [nm]	power [µW]	QE [%]
254	10.4	14
334	83.7	0.4

A preliminary AES depth profile of a Cs_2Te cathode prepared on a molybdenum sample shows a sharp interface between the substrate and the photoemissive layer. This result is in opposition with the data obtained, by the same kind of analysis, from a cesium telluride layer grew on a copper substrate. In this case infact there is a great diffusion of the photocathode elements inside the substrate itself. The different behaviour of the substrates, showed by the AES, could explain the dissimilar QE values of the same photoemissive layer grown on copper or on molybdenum [9,10].

We have evaluated also the poisonability of cesium telluride exposing it to different amount of various gases.

Fig. 6 shows a comparison of the behaviour of the QE of K_2CsSb and Cs_2Te photocathodes as a function of the exposition to oxygen: it is clearly visible the higher robustness of Cs_2Te photoemitter.

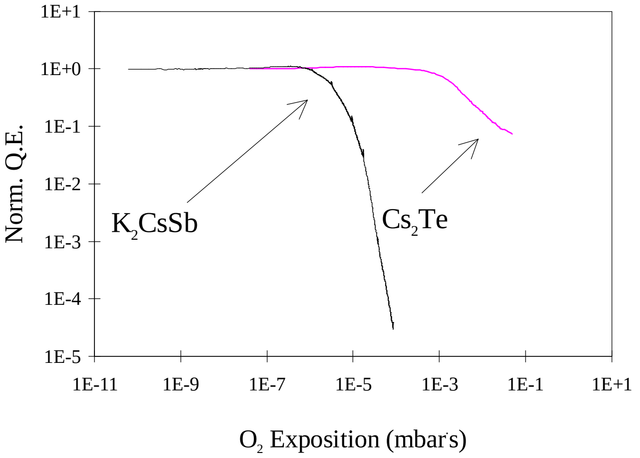

Fig. 6 - Behaviour of QE of K_2CsSb and Cs_2Te photocathodes as a function of the exposition to oxygen.

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